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3-D CHEMICALLY REACTIVE MHD FOR DUSTY SPACE PLASMAS

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SUMMARY

The overall objective of this research program is to obtain a better understanding of chemically reactive dusty space plasmas through the use of numerical solutions of the time-dependent magnetohydrodynamic (MHD) equations. The simulated results will be compared with observations where possible and with the results from previous analytic and numerical studies. The primary progress to date has been to modify our 2D MHD numerical code so it can be applied to the interaction of the solar wind with comets. This is one prototypical example in which the chemical processes have a significant effect on the flow dynamics and therefore must be included self-consistently in a realistic model. Computations have been carried out to demonstrate that the revised numerical code (without chemical kinetics or magnetic field) can adequately resolve physical processes over the approximately seven orders of magnitude in spatial scale involved in the interaction. Work has been initiated on the inclusion of chemical effects and the magnetic field and the extension to 3D.

I. SCOPE OF THE INVESTIGATION

The comet-solar wind interaction region is a large plasma physics laboratlry with no interference from wall effects occurring naturally in the space environment. We intend to exploit the data obtained in this region from spacecraft encounters with Comets P/Giacobini-Zinner, P/Halley, and P/Grigg-Skjellrup (supplemented with chemistry and dust fragmentation). The model will include photo processes, plasma- and gas-phase chemical kinetics, energy budget, consistent determination of the electron temperature and its effect on excitation, dissociation, and ionization, multi-fluid hydrodynamics with a transition to free molecular flow, production of molecular species from distributed sources of organic dust, dust charging and fragmentation, and self-consistent solar wind interaction with detailed magnetic field in three dimensions and with time dependence. The model will have application to the discrepancy of ion densities relative to state-of-the-art MHD models, the overabundance of carbon species, the pile-up region, striae formation, the existence of the inner shock, the stability of the contact surface, the magnetic ramp region, disconnection events, etc. Our ultimate goal is to better understand chemically reactive dusty space plasmas through simulations that will also be appropriate to other Solar System bodies without an intrinsic magnetic field, to the solar wind interaction with the interstellar medium, to the solar and presolar nebulae, and to planetary subnebulae of the giant plants.

II. PROGRESS DURING CURRENT REPORTING PERIOD

The simulations will ultimately be performed using a three-dimensional model. However, due to the large memory and computation time requirements for the 3-D simulations, the initial computations will be carried out using a 2-D model. These preliminary 2-D simulations serve several purposes in addition to providing useful physical insight. They will be used to determine some of the numerical parameters required in the 3-D studies, such as the grid spacing needed in order to resolve particular features and the damping that must be including to remove high-frequency oscillations. Furthermore, the first computations neglect the chemistry and magnetic field.

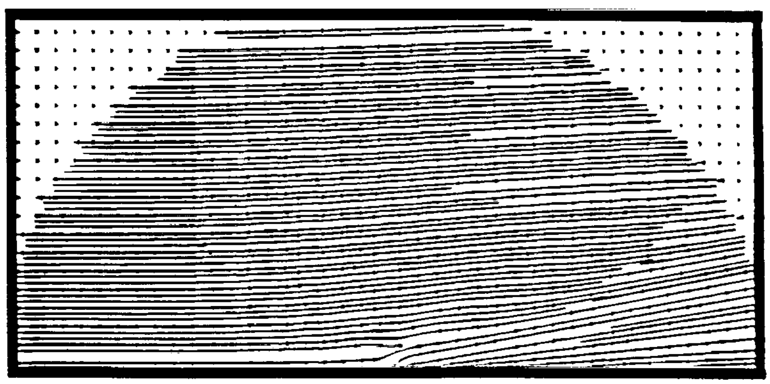
The primary effort during the current reporting period has been to demonstrate that our numerical code can adequately resolve the necessary physics occurring near the comet surface (on spatial scales less than but comparable to the comet diameter) as well as the physics in the global interaction (several orders of magnitude larger than the comet diameter). In order to illustrate this we used a 2-D code in spherical coordinates with axisymmetry about the direction of relative motion between the comet and the solar wind. The inner radius is at the comet diameter, and the outer radius is 5×10^6 times larger. The radial grid spacing increases with radius, and there is a total of 325 radial grid points. The spacing in the theta direction is set to $1°$ for a total of 180 grid points in this direction. A representative example of the variation of several physical variables in the global interaction is shown in the accompanying figure.

III. PROPOSED WORK DURING THE NEXT REPORTING PERIOD

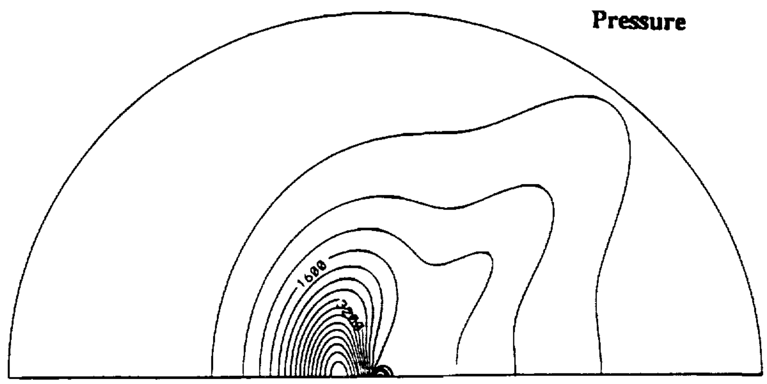
The major effort during the next reporting period will be to begin to self-consistently include the physics of the important chemical processes into the present model. The magnetic field in the solar wind will also be included in the 2-D model, which requires that the magnetic field be parallel to the direction of relative motion between the solar wind and the comet motion. In addition, the modification of our 3-D code to apply it to this study will be initiated.

A significant part of any multi-dimensional study such as that discussed here is the development of suitable graphics to assist in the physical interpretation of the simulated results. At present the plotting routines generate plots over the entire computation region as shown in the figure included here. These routines will be modified so the results can be shown on the small spatial scales necessary near the comet.

Velocity Streamlines



Pressure



Temperature